

## **Historic, Archive Document**

Do not assume content reflects current scientific knowledge, policies, or practices.



1  
Ag 84Ab 1 States  
tment of  
Agriculture  
Science and  
Education  
Administration  
op. 44  
Agriculture  
Information  
Bulletin  
Number 289

5

# Fruit Thinning of Apples and Pears with Chemicals

1576392

FRUIT THINNING SECTION  
CURRENT SERIAL RECORDS

U.S.D.A.  
NAT'L AGRIC LIBRARY  
RECEIVED  
APR 5 '82





# Fruit Thinning of Apples and Pears with Chemicals

BY

Max W. Williams, plant physiologist  
Science and Education Administration—Agricultural Research  
Tree Fruit Research Laboratory

AND

Louis J. Edgerton, horticulturist and professor  
Department of Pomology, Cornell University



United States  
Department of  
Agriculture

Agriculture  
Information  
Bulletin  
Number 289

*Prepared by*  
Science and  
Education  
Administration

## Contents

	Page
Introduction .....	1
History of thinning sprays.....	1
General information.....	2
Materials, concentration, and timing .....	3
Factors affecting fruit abscission .....	4
Weather .....	5
Crop load.....	7
Tree vigor.....	7
Spray additives.....	8
Mechanism of action of thinning sprays.....	9
Effects of thinning sprays on fruit size and yield.....	11
Influence of chemical thinning on alternate bearing.....	11
Selection of a thinning program.....	12
Methods of application.....	13
Increased return bloom by combining thinning chemicals and growth regulators .....	14
Response of spur-type trees to chemical thinners .....	15
Influence of chemical thinning agents on seed abortion and fruit size .....	15
Need for hand thinning after chemical thinning .....	16
Chemical thinning of pears.....	18
Literature cited .....	20

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

**CAUTION:** Pesticides can be injurious to humans, domestic animals, beneficial insects, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

## Conversion of Metric Units to English Units of Measure

1 hectare = 2.47 acres	3.785 liters = 1 gallon
100 liters = 26.42 gallons	473 milliliters = 1 pint
454 grams = 1 pound	946 milliliters = 1 quart
28.4 grams = 1 ounce	

# Fruit Thinning of Apples and Pears with Chemicals

By Max W. Williams and Louis J. Edgerton<sup>1</sup>

## Introduction

The removal of excess fruit from apple trees is an essential orchard practice. Chemical thinning of apples reduces biennial bearing and increases fruit size, color, and quality. Fruit size at harvest is directly related to the earliness and degree of fruit thinning, provided the tree and spur vigor are adequate.

In the past, thinning was done by hand. Chemical thinning has been developed and is now used with some followup hand thinning.

## History of Thinning Sprays

Fruit thinning by hand has been practiced since early times, mainly to improve fruit size and quality. Little if any attempt was made to control cropping by thinning until Russell and Pickering (36)<sup>2</sup> showed convincingly that the alternate bearing habit could be controlled if thinning was practiced at the bloom stage instead of 6 to 8 weeks after bloom as was the usual commercial practice. During the 1920's and 1930's, blossoms were thinned with small hand scissors; however, the hand removal of the myriad excess flowers in the typical "on-year" mature tree was not practical on a large scale. The first attempts to use chemical sprays for thinning apples were designed to eliminate a major portion of the flowers and permit the tree to differentiate flower-buds for bloom the succeeding year.

Bagenal et al. (2) recognized that the drop of immature fruit from a healthy tree was increased by chemical sprays applied to control pests. They observed that "lime-sulphur" (calcium polysulfide) induced excessive drop of young apples. The first conscious attempts at chemical elimination of flowers were made by Auchter and Roberts (1). Several of the common spray materials of that era were used in their tests and included calcium and sodium polysulfide, copper sulfate, oil emulsion, and zinc sulfate. In many instances, prebloom applications of these materials not only killed the flowers but also injured the spur tissues and foliage. The tar distillates, when applied at the cluster bud stage, were the most effective in preventing fruit set.

The main object of early work on chemical thinning was to find a practical method of entirely preventing fruit set on certain apple cultivars. In 1940, promising results were reported in reducing fruit set with a commercial preparation of dinitrocyclohexylphenol (32). That same year, a commercial preparation containing

DNOC,<sup>3</sup> was shown to prevent pollen germination when applied to the flower stigmas (34). Initial tests indicated this material had considerable promise as a spray on apple trees in bloom to reduce fruit set.

For several years after 1940, numerous investigators experimented to evaluate the various forms of DNOC for thinning fruit. At first, it appeared that the phenol forms of DNOC were likely to result in russeted or misshapened apples; however, extensive comparison of the acid form of DNOC with the sodium salt showed little or no difference in the two materials when used at equivalent concentrations (7).

While an effort was being made to adapt DNOC as a bloom spray for thinning apples, information began to appear on the effects of hormone-type chemicals on fruit set. In 1939, it was learned that NAA and NAAM would prevent the preharvest drop of apples (20). This led to attempts by Burkholder and McCown (10) to increase the set of 'Starking Delicious' apples by applying NAA sprays during bloom. NAA reduced set from 15 to 77 percent, depending on the concentration (10 and 50 parts per million (p/m)). NAAM at 50 p/m used in a similar manner reduced the number of spurs setting fruit by 34 percent. NAA at 10 p/m slightly injured young foliage. Severe injury in the form of epinasty, scorching, and leaf drop resulted from 50 p/m. No visible foliage injury was caused by the NAAM spray. The results indicated that NAAM reduced the set of fruit but less effectively than NAA at the same concentration.

When the branch-unit method was used, bloom sprays of NAA at concentrations of 100 to 300 p/m seriously overthinned 'Delicious' and 'Gano' and deformed the leaves (35). Similar results were obtained on 'Arkansas Black' with the same concentrations of NAA and NAAM. The NAA was more potent than NAAM in reducing set and causing leaf injury.

Considerable attention was given to the timing of NAA sprays. Davidson et al. (13) were the first to show that NAA could be used as a postbloom spray. They obtained effective thinning when the sprays were applied as late as 2 to 3 weeks after bloom.

Early experiments with NAAM were conducted by Burkholder and McCown (10) and Schneider and Enzie (37); however, full-scale experiments were not performed until Hoffman (26) revived interest in this compound with his investigations of the possibility of avoiding the difficulties associated with NAA sprays. Using the early postbloom applications, he found that NAAM sprays were milder than NAA and did not damage the foliage.

<sup>1</sup>Williams is a plant physiologist, Science and Education Administration, U.S. Department of Agriculture, Wenatchee, Wash. 98801; Edgerton is a horticulturist and professor, Department of Pomology, Cornell University, Ithaca, N.Y. 14853.

<sup>2</sup>Italic numbers in parentheses refer to Literature Cited, p. 20.

<sup>3</sup>See table 1 for chemical names of fruit-thinning substances.

Table 1.— *Various chemicals used for thinning apples*

Symbol or common name	Chemical name	Trade names
DNOC	sodium 4,6-dinitro-ortho-cresylate	Elgetol
NAA	1-naphthaleneacetic acid	Fruitone-N, Fruit Fix, Fruit Set, Stafast, Kling-Tite
NAAm	1-naphthaleneacetamide	Amid-Thin, Anna-Amide
Carbaryl	1-naphthyl (N-) methylcarbamate	Sevin
Ethephon	(2-chloroethyl) phosphonic acid	Ethrel, Cepha

From 1953 to 1959, hormone-type chemicals and DNOC came into general commercial use on apples in some fruit areas of the United States. Research throughout the country during that period was generally directed toward obtaining information on timing and concentration of these sprays and factors affecting results.

In 1958, a new insecticide, carbaryl, was tested on apples in some of the principal fruit-growing areas of the country. Carbaryl was formulated, at a 50-percent concentration, as a wettable powder. As an insecticide, carbaryl was used at the rate of 2 kg/ha, and the first application was generally made 10 to 21 days after full bloom. In several instances, fruit set was reduced moderately by carbaryl applied during this period.

Batjer and Westwood (9) conducted several experiments to evaluate the thinning properties of carbaryl on 'Delicious' apples. This chemical was found to be a highly effective thinning agent; thus, another chemical was added to the arsenal of thinning sprays for use by orchardists.

Since 1964, the only chemical added to the commercial thinning program is ethephon. It is used mainly on 'Golden Delicious' (16, 49). In Australia, Veinbrants (46) demonstrated the value of ethephon used at lower rates on 'Delicious'. In the United States, thinning results with ethephon are usually too variable when used as a post-bloom thinner on 'Delicious' and other cultivars. Further tests are needed to determine its value as a bloom or immediate postbloom spray.

Most recent publications on fruit thinning deal with variations in response of cultivars in different apple-growing areas or with interaction of growth regulators on thinning agents (11, 17, 37, 40, 43). A new chemical, oxamyl,<sup>4</sup> was tested for thinning, but some fruit russeting occurred (11). Oxamyl is not registered for use as a chemical thinner and should not be used commercially.

Another thinning program for improving fruit size and shape of 'Delicious' in Western United States is the combination of Promalin and Elgetol, a commercial formulation of DNOC. This spray is applied at 80 percent of full bloom. The recommendation is to use 1 or 2 pints of Promalin plus 4 pints of Elgetol in 100 or 200 gal of water and apply to one acre (59). Promalin is registered for improving the size and shape of 'Delicious',

and Elgetol is registered as a thinning agent. The time of applications of Promalin and Elgetol is the same at the 80-percent full bloom stage.

### General Information

A satisfactory thinning spray will remove enough fruit to assure an adequate return bloom the following season. Presently, growers try to slightly overthin with chemicals in an attempt to avoid supplemental hand thinning. Hand thinning, if needed after chemical thinning, can be done over a relatively long period without seriously affecting the next year's crop or reducing the size and quality of the current fruit crop.

Thinning can be accomplished at bloom time and during the early postbloom period. Strongly biennial cultivars may require both a bloom and postbloom spray program for adequate thinning and return bloom. The blossom-thinning chemical DNOC is caustic and burns the flower parts, preventing pollination and/or fertilization (fig. 1). Thus, application time for the bloom spray is critical. The effective period for DNOC in Western United States is from 1 to 3 days after the trees have reached the 80-percent full bloom stage. When blooming is spread over several days, the timing of a DNOC spray application is difficult, and the results may be disappointing. For this reason, and the fact that rain can reactivate the chemical, the bloom sprays are not used in the apple-growing areas in Eastern United States; however, with careful monitoring of weather conditions, DNOC at lower concentrations can be used effectively in moderately rainy areas.

Also, DNOC applied at the beginning or end of a long bloom period can be helpful in removing unwanted fruit. In cool growing areas, a split application may be needed to coincide with blooming.

The postbloom thinning programs can be used in any or all apple-producing areas. Some of the postbloom chemicals are hormone types and are used to upset the natural hormone balance of the tree. Others are nonhormonal but cause stress and embryo abortion.

The mode of action of the postbloom thinning chemicals is not entirely known. They are generally believed to interfere with the endogenous hormones that control the flow of nutrients to the developing fruit. Embryo abortion may precede or accompany fruit abscission.

<sup>4</sup>Methyl N', N'-dimethyl-N-(methylcarbamoyl)oxy-1-thioxamidate.



PN-7011



PN-7012

Figure 1.—Damage from DNOC spray to flower pistils of 'Golden Delicious' apple, indicating healthy (left) and damaged (right) stigma end of style. Note dark ends of styles in right-hand figure.

High temperature or chemical stress of any kind applied to apple trees during the early postbloom period will increase fruit abscission.

### Materials, Concentration, and Timing

Chemicals presently in use are listed in table 1. Current year's spray schedules should be observed for any recent changes in registration. DNOC, a blossom thinner, is used at a concentration from 160 to 480 g/100 L of water. NAA, NAAM, and carbaryl are postbloom thinners that are applied from 10 to 25 days after full bloom. NAA is used at concentrations from 2 to 15 p/m. Ethephon is combined with NAAM for postbloom application to 'Golden Delicious'. The rate for Ethephon is 300 p/m, and it is applied with NAAM at 10 to 21 days after bloom.

In most of the United States, 2 to 5 p/m of NAA plus a wetting agent is used for thinning 'Delicious'. NAA is sometimes used without a wetting agent at 10 to 15 p/m. NAAM is not used on 'Delicious' because of "pygmy" fruit formation (fig. 2), but can be used effectively on 'Golden Delicious', 'Winesap', and 'Tydemans Red' at concentrations from 17 to 35 p/m. Up to 50 p/m of NAAM may be used without a wetting agent. Carbaryl is used on 'Delicious' at concentrations from 30 to 60 g/100 L, on spur-type 'Delicious' 60 to 120 g/100 L, and on 'Golden Delicious' from 120 to 180 g/100 L of water. On all cultivars, carbaryl is applied at 10 to 25 days after full bloom.

The time to apply sprays can be determined either by fruit size or by days after full bloom. Some researchers have shown that better results are obtained if timing is based on fruit size (14, 45); but, in practice, it is difficult to apply sprays when the fruit are all of a certain size. Fruit trees often blossom over several days or longer; thus fertilization occurs at different times with the result that fruit sizes differ. Differences in tree and spur vigor also differentially affect fruit growth rates; therefore, fruit sizes on any given tree or among trees can vary considerably. In many apple production areas, however, postbloom growth is later because of cool weather. In such areas, fruit size is the best guide for time of chemical application. For reliable results by this method, use the same type of fruit, either the center "king bloom" or "side bloom," each year. A minimum random sample of 10 fruit from each of 10 trees is necessary to determine average fruit size in a given orchard.

Many years of experience with chemical thinners under central Washington conditions indicate timing of sprays on a days-after-full-bloom basis is both satisfactory and practical. Growers with large acreages should begin spraying at the earliest recommended date. Spraying large blocks over a period of days, whether by choice or by necessity, lowers the risk of overthinning. In years with unusually warm or cool periods before time of thinning, the recommended time of application is adjusted according to the stage of plant develop-



Figure 2.—Branches and spurs from 'Red Delicious' apple. Left, control (unthinned); center, spray thinned with carbaryl 10 days after bloom; right, pygmy fruit from NAAm spray 10 days after bloom.

PN-7010

ment. Since warm temperatures promote rapid growth, thinning sprays should be applied earlier.

Apple trees are considered to be in full bloom when 80 percent of the flowers on 3- and 4-year-old spurs are open on the north side of the tree. DNOC should be applied at this time for maximum thinning. DNOC applications later than early petal fall (2 to 4 days after flower opening) are ineffective because pollination and fertilization will have already occurred. Spur-type 'Golden Delicious' and some spur-type 'Delicious' bloom over a period of several days. When this occurs, DNOC can be applied to the bottom of the tree with a speed sprayer, and later the top can be treated by using the handgun method of application.

With postbloom sprays, the effective thinning period is for 1 to 2 weeks and up to 3 weeks, depending on the weather. Spray application should be spread over the effective thinning period to minimize the effect of adverse weather conditions occurring after the spraying. Suggested concentrations and spraying schedules for some common cultivars are given in table 2 for varieties and conditions prevailing in the Wenatchee, Wash., area and in table 3 for varieties and conditions prevailing in the Ithaca, N. Y., area. Local authorities

should be consulted for specific concentrations and timing recommendations.

A range in concentrations is indicated in each of the tables. This is done to take into consideration some of the variables that affect response to the thinning application as outlined in table 4. These factors are also discussed in some detail in a later section. With conditions that make the trees easy to thin, the lower concentrations should be used; whereas, the higher rates will be needed when conditions indicate a more difficult thinning problem. In deciding upon the final concentration and thinning combination, the previous experience of growers with their own trees and that of other growers in their specific areas are valuable guides.

### Factors Affecting Fruit Abscission

Many factors affect the thinning effectiveness of a particular chemical. A proper evaluation of the conditions that would enhance thinning in an orchard could make a difference of thousands of kilograms in annual cropping. A guide for this evaluation is presented in table 4. Each season, those responsible for fruit-thinning programs should review the available publications on chemical thinning. Batjer (3), Batjer and Billingsley (4),

Edgerton (15), Grausland (21), Hoffman (26), and Thompson (44) have described the important factors to be considered in a chemical thinning program. Weather and tree condition are the most important factors affecting the absorption and physiological action of chemicals. The method of application, the amount of

chemical to use, and the time of application can be adjusted if weather and tree conditions are known.

### Weather

Cool, wet weather, either before or after application, will precondition the leaves and increase chemical ab-

Table 2.—*Chemical thinning program for apples, Wenatchee, Wash.*

Bloom stage and cultivar	Chemical	Spray concentrations <sup>1</sup>				Effective period <sup>3</sup>
		Dilute	Concentrate <sup>2</sup>			
		<i>P/m</i>	<i>G/100 gal</i>	<i>G/100 L</i>	<i>G/ha</i>	
Bloom spray:						
Nonspur Delicious	DNOC	160-240	61-91	16-24	450-670	( <sup>4</sup> )
Golden Delicious, Jonathan, Newtown, Winesap, Tydemans, Spur-Delicious.	DNOC	240-480	91-182	24-48	670-1350	( <sup>4</sup> )
Postbloom sprays:						
Golden Delicious	Carbaryl	600-1200	228-456	60-120	1680-3360	10-25
	NAAm	17-34	6.5-13	1.7-3.4	50-100	7-20
	NAA <sup>5</sup>	3-5	1.1-1.9	0.3-0.5	10-15	10-20
Winesap	Carbaryl	450-600	171-228	45-60	1260-1680	10-15
	NAAm	17-34	6.5-13	1.7-3.4	50-100	7-20
	NAA <sup>5</sup>	3-5	1.1-1.9	0.2-0.5	10-15	10-20
Delicious	Carbaryl	300-600	114-228	30-60	840-1680	10-25
	NAA <sup>5</sup>	3-5	1.1-1.9	0.2-0.5	10-15	10-20
Jonathan, Newtown, Rome.	Carbaryl	300-600	114-228	30-60	840-1680	10-25
	NAA <sup>5</sup>	3-5	1.1-1.9	0.3-0.5	10-15	10-20

<sup>1</sup>Active ingredient.

<sup>2</sup>Based on the application of the dilute spray solution at the rate of 2800 L/ha.

<sup>3</sup>Days after full bloom.

<sup>4</sup>80-percent full bloom.

<sup>5</sup>The amount of NAA required when used alone without an appropriate surfactant is double or triple the amounts shown in table.

Table 3.—*Chemical thinning program for apples, Ithaca, N.Y.*

Stage and cultivar	NAAm <sup>1</sup>	NAA <sup>1</sup>	Carbaryl <sup>2</sup>		Combinations <sup>3</sup>		
	--- P/m ---		Lb/100 gal	or g/100 L	P/m + lb/100 gal	or g/100 L	
Petal fall spray:							
Lodi, Transparent	35-50	-	-	-	NAA 5-10 + carbaryl 1-2	120-240	
Quinte, E. McIntosh	35-50	-	-	-	NAA 5-10 + carbaryl 1-2	120-240	
Macoun	-	5-10	-	-	-	-	
Postbloom sprays:							
Tydemans	-	5-10	1-2	120-240	-	-	-
Wealthy	-	15-20	-	-	NAA 5-10 + carbaryl 1-2	120-240	
Paula Red, Jonamac	-	5-10	1-2	120-240	-	-	-
Jonathan	35-50	5-10	1-2	120-240	-	-	-
Spartan	-	10-15	-	-	NAA 5-7.5 + carbaryl 1-2	120-240	
McIntosh, Cortland	35-50	5-10	1-2	120-240	NAA 2-3 + carbaryl 1-2	120-240	
R. I. Greening	35-50	10-15	1-2	120-240	NAA 5-7.5 + carbaryl 1-2	120-240	
Delicious, Empire	-	5-10	1-2	120-240	-	-	-
Idared	-	-	1-2	120-240	-	-	-
Northern Spy	35-50	-	1-2	120-240	NAA 2-3 + carbaryl 1-2	120-240	
Golden Delicious	-	15-20	-	-	NAA 5-10 + carbaryl 1-2	120-240	
Rome Beauty	-	10-15	1-2	120-240	NAA 5-7.5 + carbaryl 1-2	120-240	

<sup>1</sup>Lower concentrations are suggested for conditions favorable for thinning.

<sup>2</sup>When applied solely for thinning, the lower concentration is generally used. If insecticidal activity is also desired, use the higher rate. Bees should be removed from the orchard before applying carbaryl.

<sup>3</sup>NAAm at 25 to 50 p/m can be combined with the carbaryl in place of the NAA if desired.

NOTE: Dashes indicate lack of good response.

Table 4.—*Conditions affecting ease of fruit thinning with chemicals*

Trees are easy to thin when:	Trees are difficult to thin when:
<ol style="list-style-type: none"> <li>1. Fruit spurs on the lower, shaded inside branches are low in vigor.</li> <li>2. Moisture or nitrogen supply is inadequate.</li> <li>3. Root systems are weakened by disease or physical damage.</li> <li>4. Bloom is heavy, especially after previous heavy crops.</li> <li>5. Young trees have many vigorous upright branches.</li> <li>6. Thinner are applied to self-pollinated or poorly pollinated fruit.</li> <li>7. Fruit set is heavy on easily thinned cultivars, such as 'Delicious'.</li> <li>8. The cultivars tend to have a naturally heavy June drop.</li> <li>9. Fruit sets in clusters rather than as singles.</li> <li>10. Bloom period is short and blossom-thinning sprays are used.</li> <li>11. High temperature is accompanied by high humidity before or after spraying.</li> <li>12. Blossoms and young leaves are injured by frost before or soon after spray application.</li> <li>13. Foliage is conditioned for increased chemical absorption by prolonged cool periods.</li> <li>14. Rain occurs before or after spray application.</li> <li>15. Prolonged cloudy periods reduce photosynthesis before or after application of chemicals.</li> </ol>	<ol style="list-style-type: none"> <li>1. Fruit are set on spurs in well-lighted areas of tree (tops and outer periphery).</li> <li>2. Trees are in good vigor with 12 to 18 inches of terminal growth with no mineral deficiencies.</li> <li>3. Older trees in good vigor have a mature bearing habit.</li> <li>4. Light bloom or light fruit set occurs with the exception of young trees.</li> <li>5. Trees have horizontal fruiting branches.</li> <li>6. Insects are active on cross-pollinated cultivars.</li> <li>7. Limbs and spurs have been slightly girdled following moderate winter injury.</li> <li>8. Biennial bearing trees are in the "off year."</li> <li>9. Fruit set in singles rather than in clusters.</li> <li>10. Cultivars such as 'Golden Delicious' and heavy setting spur types are to be thinned.</li> <li>11. When ideal fruit growth occurs before and after time of thinning.</li> <li>12. Low humidity causes rapid drying of the spray and decreased absorption occurs before and after spraying.</li> <li>13. Cool periods follow bloom, without any tree stress.</li> <li>14. Endogenous ethylene production is low.</li> <li>15. Bloom is light and a high leaf-to-fruit ratio exists.</li> </ol>

sorption of all thinning agents. Cool temperatures for a few days before application soften the leaf cuticle. Frosty conditions may weaken flower parts, reduce pollen tube growth and fertilization, and increase the tendency of fruitlets to abscise. Wet or damp conditions at the time of application or shortly after will prolong drying of the leaves and increase chemical absorption. High relative humidity alone, without rain, either before or after spraying will also increase chemical uptake.

One hazard associated with dinitro materials is rain following the sprays (6). Material deposited on the leaves may be rewetted, and the additional absorption sometimes results in serious foliage injury and excessive reduction in fruit set. In controlled studies, 20 hours of rain 1 day after spraying resulted in much greater DNOC absorption than rain 3, 5, or 7 days after the spray (50). Likewise, 20 hours of rain following the spray resulted in much greater absorption of DNOC than 1, 5, or 10 hours of rain. Also, rain at 70°F on trees previously sprayed with DNOC resulted in significantly greater absorption than rain at 50°F. These results indicate that a prolonged, warm rain shortly after spray application greatly enhances DNOC

absorption. Chemical thinning experiments in the field have led to the same conclusion. Severe overthinning and foliage burn have usually developed when DNOC sprays were followed immediately by rain. Greater thinning has also been seen in areas of an orchard where air drainage is poor and the leaves remain wet longer than in more favorable sections of the same orchard.

In later experiments, Westwood et al. (52) found that absorption of DNOC, as measured by leaf injury, was directly proportional to the duration of a high humidity treatment (without rain) administered before the spray application. Also, high humidity following DNOC sprays resulted in the same amount of injury as a similar period of rain. Under field conditions, thinning with DNOC is almost invariably mild under conditions of no rain, low relative humidity, and moderate temperature before and after spraying.

Low temperature at or near the frost level also influences results obtained from DNOC sprays. In 1952, temperatures at the frost level occurred 2 days after spraying 'Delicious'. Counts the day after the frost revealed that 10 percent of the flowers were killed from

frost on the check trees and 36 percent on the sprayed trees. In later years, it was established that more blossoms were killed by frost on trees that had been sprayed than on adjacent unsprayed ones. DNOC seems to increase the susceptibility of flowers to low-temperature injury. Extensive observation also indicates that thinning increases on sprayed trees when temperatures hover around the frost level, even though few or no blossoms are killed by freezing.

Factors affecting the absorption of NAA and NAAM sprays have received considerable attention. Under controlled greenhouse conditions, the time required to dry NAA sprays and the temperature at which they dried affected NAA absorption (50). The longer the time required to dry the sprays and the higher the drying temperature, the greater was the absorption; however, in the field, absorption may be greater under cool humid conditions where the leaves remain wet for a long time. Also, NAA absorption increased when apple trees were exposed to frost temperatures of 28°F a few days before treatment (51).

Absorption efficiency is influenced in part by the physiological status of the plant and particularly by the cuticle, which is considered a major barrier to absorption. Environmental factors, such as humidity, affect both the thickness and composition of plant leaf cuticle (27). Westwood et al. (52) demonstrated that the cuticle layer on apple leaves exposed to 100 percent relative humidity for several days was altered in a manner that greatly affected the spreading characteristics and absorption of DNOC sprays (fig. 3). For DNOC and hormone-type sprays, variability resulting from environment probably is largely due to differences in absorption efficiency. The effect of these conditions on the leaf cuticle is apparently a major factor in this process.



PN-7013

Figure 3.—Spreading characteristics of DNOC spray on apple leaves as influenced by differences in humidity before spraying. Leaves at the right were exposed to 30 to 50 percent relative humidity and those at the left to 100 percent relative humidity 7 days before spraying. Note the heavy spheroid beading in contrast to the complete spreading of the spray solution (52).

High temperature following cool periods will cause tree stress and tend to increase the action of chemical thinners. Walsh et al. (47) have found an increase in ethylene evolution from spurs and fruits treated with NAA. After spraying with NAA, hot or cold conditions, which induce stress, can affect the amount of ethylene produced, which in turn can alter the amount of fruit abscission.

### Crop Load

Trees cropped heavily the previous year are more easily thinned. Some cultivars, such as 'Delicious', just beginning to bear fruit should not be treated with chemicals. When set is heavy on such trees, "June drop" may be extensive and the resulting crop light. Young, spur-type trees, which have acquired the bearing habit of old trees, can be thinned safely with chemicals, but the concentration of chemical should be reduced to about one-half that used on older trees.

The amount of bloom on the tree affects the thinning response. Trees with heavy bloom are more susceptible to chemical treatment than trees with light bloom. Generally, when bloom is light, fruit set per spur is heavy, and the effect of chemical thinning is reduced. Chemical thinning is usually not needed when bloom or fruit set is light; however, such trees will not be seriously overthinned if sprayed, as they might be if the trees had a heavy bloom. Table 5 shows that fruit set per 100 blossoming spurs on light-bloom trees was substantially greater than on heavy bloom trees. Thinning sprays were less effective in reducing the amount of fruit set per cluster on light-bloom trees. About twice as many apples set per 100 blossoming spurs on trees with only one-half the amount of bloom. Therefore, trees that vary in bloom from 40 to 95 percent can, after June drop, have about the same amount of fruit set regardless of the percentage of bloom (see last column of table 5).

### Tree Vigor

Tree vigor is a major factor in thinning response. The physiological or growth status of the tree affects results with thinning sprays. Overthinning is less likely when trees have normal vigor. Trees are more susceptible to the action of thinning sprays when suffering from effects of inadequate light (closely planted and lightly pruned), winter injury, wet soils, low nitrogen level, or any condition that may affect normal growth and fruit set. Most of these conditions induce physiological stress which favors fruit abscission.

Trees suffering from the effects of any of the above conditions may set less fruit than normal trees. Further, the set may be "weaker" and more easily thinned with spray chemicals. All chemical thinners reduce fruit set more on weak wood lacking in food reserves. Even on normal trees, thinning is heavier on the weak, shaded wood of the lower and inside branches of the tree. The influence of spur vigor was illustrated by a positive correlation between bud diameter and resistance to the action of NAA (38). Also, fruit from the more vigorous center "king" blossoms showed a sig-

Table 5.—*Effect of thinning sprays on apples with light and heavy bloom*

Cultivar and orchard	Material	Amount of bloom	Spurs flowering		Fruit per 100 blossoming spurs		Fruit set per 100 spurs
			Check	Sprayed	Check	Sprayed	
			Percent	Percent	Number	Number	Number
Golden Delicious:							
Bond	DNOC	Light	47	51	131	83	42
	--do--	Heavy	96	94	90	45	43
Schell	--do--	Light	46	47	150	102	48
	--do--	Heavy	92	93	97	58	54
Delicious, View	Carbaryl	Light	40	45	94	81	36
	--do--	Heavy	95	80	58	35	28

Source: Batjer and Billingsley (4).

nificantly greater tendency to resist the action of NAA and DNOC sprays (7).

Many observations indicate that trees that have cropped heavily the year before are usually more easily thinned, even though they have a heavy bloom that sets normally. In such instances, a lower carbohydrate reserve, because of the previous heavy crop may enhance the effectiveness of the thinning chemical.

Young trees are more easily thinned than the older ones with established bearing habits. 'Delicious' trees (5 to 8 years old) that are just beginning to bear may not set fruit in proportion to the amount of bloom. Even young trees of cultivars that tend to set heavily (for example 'Golden Delicious') are more easily thinned than older trees. This response of young trees to thinning sprays is perhaps related to their faster vegetative growth and a consequent reduction in carbohydrates and other reserves available to the young, developing fruit in the early postbloom period. Young trees, particularly 'Golden Delicious', and spur-type 'Delicious' can be thinned safely with chemicals, but the spray concentration should be adjusted to about one-half of the amount used for older trees.

### Spray Additives

Several investigators (18, 23, 50, 51) found that adding surfactants (wetting agents) to spray mixtures greatly enhanced foliar absorption of growth regulators and urea. When Tween 20 was added to only 2 p/m of NAA, 'Golden Delicious' was significantly thinned (23). This finding suggested a surfactant might be used with relatively low concentrations of NAA and NAAM, thereby preventing less variability in results due to environment. Westwood and Batjer (51), working with young apple trees under controlled conditions, found that adding Tween 20 tended to minimize the differences in NAA absorption resulting from environmental factors. In greenhouse experiments, adding a suitable surfactant to NAA sprays enhanced NAA uptake under conditions unfavorable for absorption (low humidity

and rapid drying), but had little or no effect under conditions that favored high absorption (high humidity and slow drying) (51).

The results of these experiments suggest that a suitable surfactant reduced the variability due to widely different environmental conditions. Of 19 surfactants tested, Tween 20 and Colloidal Spray Modifier were the most effective. Colloidal Spray Modifier was generally preferred over Tween 20, which foams excessively. Colloidal Spray Modifier has been replaced by an equally effective wetter known as Regulaid (polyoxyethylene-polypropoxypropanol dihydroxypropane alkyl Z-ethoxyethanol, Colloidal Products Corp., California).

The type and amount of surfactant, whether ionic or nonionic, can affect the amount of chemical absorbed. Freed and Montgomery (19) found that foliar penetration of aminotriazole was influenced more by the chemical nature of the surfactant added than by the reduction of surface tension. Although surface tension reduction and surface wetting were important, the molecular interaction of surfactant and herbicide was of equal or greater importance. This conclusion was substantiated by the successive increases in NAA absorption as the concentration of surfactant was increased far beyond that required for minimum reduction of surface tension (51).

From 1958 to 1961, many field trials were conducted in central Washington to determine the feasibility of incorporating a surfactant with NAA and NAAM thinning sprays. Results of these trials are given in table 6. A low concentration of the chemicals plus the surfactant was as effective as a high concentration of the chemical without the additive. The standard errors of the means in trials involving the surfactant were about the same as those for corresponding check treatments. Therefore, the addition of a surfactant in these experiments did not reduce variability, as might have been expected from controlled experiments (51). Nevertheless, the inclusion of an additive with hormone-type thinners is now a general practice.

Table 6.—*Effectiveness of NAA and NAAm thinning sprays with and without the addition of Tween 20*

Cultivar treatment <sup>1</sup>	Concen- tration of NAA and NAAm	Trials	Fruit set compared to untreated check
	P/m		
		Number	Percent
Delicious:			
NAA	10	9	65 ± 11
NAA + Tween 20	3	9	59 ± 12
NAAm	50	3	79 ± 15
NAAm + Tween 20	17	3	82 ± 15
Winesap:			
NAA	10	6	60 ± 22
NAA + Tween 20	3	6	60 ± 21
NAAm	50	9	70 ± 18
NAAm + Tween 20	17	9	72 ± 16
Golden Delicious:			
NAA	15	4	45 ± 12
NAA + Tween 20	5	4	52 ± 14
NAAm	50	6	53 ± 18
NAAm + Tween 20	17	6	57 ± 16

<sup>1</sup>Tween 20 was used at a concentration of 1 L/800 L of water.  
Source: Batjer and Billingsley (4).

### Mechanism of Action of Thinning Sprays

Studies to determine the mechanism of thinning chemicals have lagged behind investigations designed to work out the practical details of spray applications. Questions as to why thinning sprays result in the drop of some fruit and not others and the mechanism involved in the action of these sprays have often been asked. In recent years, many experiments have been conducted to obtain information on the complex phenomenon of thinning.

A 0.25-percent concentration of DNOC completely prevented pollen germination when applied to the stigmas of apple flowers (31). In later work, DNOC applied to open flowers inactivated pollen tubes that had already grown halfway down the style of the pistil (24). This depth approximates that of pollen penetration 1 day after the pollen has been applied to the stigma. The speed of pollen tube penetration is directly related to temperature. Discoloration of the tips of the styles indicates spray damage (fig. 1).

The fact that set is reduced appreciably when DNOC sprays are applied from 1 to 3 days after full bloom indicates that many flowers already fertilized are prevented from developing fruit by the indirect action of the spray material. This type of thinning results from the caustic action of the chemical on the stem and other exposed parts of the flower. Also, fruit set is believed to be affected through temporary alteration of growth processes when both flower and leaf tissue absorb the chemical, which increases the amount of physiological stress.

The work already done has shown that the postbloom thinning mechanism is very complex. It has been accepted for some time that NAA temporarily delays the abscission of young fruit (43). Struckmeyer and Roberts (42) proposed that the delay in natural abscission increased nutritional competition, thus reducing the number of fruit after the June drop period. This theory is not now generally accepted, because NAA does not always delay abscission. Often, NAA thins moderately to heavily without delaying fruit drop (4).

While Luckwill (29) presented evidence that NAA primarily thins through an effect on seed abortion, more work is needed to clarify the fundamental nature of this mechanism. In later work by Luckwill and Lloyd-Jones (30), only 0.2 percent of the radioactivity applied as NAA to the leaves was recovered from the seed after 5 days, and none of it was in the form of unmetabolized NAA. Results of the work support the view that seed abortion and the consequent abscission of the fruitlets is not due to the direct action of NAA itself. Rather, they indicate that abortion is caused by a breakdown product which, unlike NAA, has no auxin properties.

Opposed to the "seed abortion concept," Marsh et al. (33) found that NAA-type materials markedly reduced fruit set of 'McIntosh' and 'Golden Delicious' without significantly affecting the number of viable or aborted seed in young dropping or persisting fruit. Work in the Northwest gave similar results with 'Golden Delicious', 'Winesap', and 'Delicious' (8). With NAA on 'Delicious', no relationship was found between the number of viable seed and thinning (table 7).

Considerable progress has been made in determining how carbaryl functions as a chemical thinner. This chemical greatly reduced the viable seed content of persisting 'Delicious', but not 'Golden Delicious', 'Jonathan', or 'Winesap' (8). Carbaryl sprays thin all cultivars about equally.

Table 7.—*Effect of NAA and carbaryl on seed content and fruit set of 'Delicious' apples*

Orchard	Year	Treatment	Viable seed in persisting fruit	Fruit set
			---Percent of check---	
Farrington	1959	NAA	95	34
Welch	1954	--do--	88	89
Bond	1960	--do--	74	78
View	1960	--do--	61	74
Parson	1961	carbaryl	101	47
View	1961	--do--	80	41
Larson	1961	--do--	79	70
Robinson	1962	--do--	64	63
View	1962	--do--	59	51
Robinson	1960	--do--	39	74
View	1959	--do--	24	74

Source: Batjer and Billingsley (4).

When both ring- and side chain-labeled C<sup>14</sup> carbaryl were applied to spur leaves of 'Delicious' apples, radioactivity moved into the vascular tissue, and after 15 days no activity was detected in the seeds (57). With either leaf or fruit applications, the amount of radioactivity was greatest in the vascular tissues of the fruit. When fruit were dipped in C<sup>14</sup> carbaryl, vascular tissue became radioactive. Thus, two facts, (1) the apparent absence of activity in the seed in all of the experiments with C<sup>14</sup> carbaryl (57) and (2) the lack of correlation between the number of viable seed in persisting fruit and the percentage of thinning, suggest seed abortion is not the primary cause of fruit abscission. In 1964, Williams and Batjer (57) proposed "interference with transport" as the primary factor in fruit thinning. Evidence for the proposal was presented earlier by Teubner and Murneek (43), who found that embryos aborted without fruit abscission. They concluded the two phenomena were independent.

Seed abortion and fruit abscission are undoubtedly the result of chemically and/or environmentally induced physiological stress. Walsh et al. (47) found an increase in ethylene production from fruiting spurs after application of NAA. Ethylene evolution was correlated with leaf epinasty. Whether ethylene is directly responsible for fruit abscission or is merely a symptom of stress has not been determined. Application of an endogenous ethylene inhibitor — aminoethoxyvinylglycine (AVG) — completely eliminated June drop on several apple cultivars (62). AVG-treated fruit had the same seed complement as untreated fruit; thus, the lack of June drop was not because of an increase in parthenocarp. We must conclude, however, that AVG prevents seed abortion by lowering ethylene levels at the abscission zone, which results in less June drop.

An abscission zone forms between the fruit stem and the spur before drop occurs. It may be postulated that ethylene is produced in the spur and promotes senescence and abscission. As a result, the cells separate at the abscission zone, which interferes with the transport of nutrients; the seeds then abort; and the fruit eventually drop. The "interference of transport theory" (57) is acceptable on the basis that formation of the abscission zone prevents movement of some but not all substrates into the seed and fruit, but the real cause of abscission is likely a change in metabolism, which leads to the production of ethylene and formation of the abscission zone. Auxins, such as NAA, if used in high concentrations, can alter metabolism in the abscission zone and prevent fruit drop (40).

The extent of fruit abscission may be determined by the total amount of ethylene induced collectively by the chemicals, the environmental stress, and the management practices which affect the vigor of the spur. Ethylene production, however, may be the result of an earlier metabolic change. AVG interferes with the conversion of methionine to ethylene, lowering endogenous ethylene production and ultimately preventing June drop. Physiological and environmental stress undoubtedly play major roles in fruit abscission.

Seed abortion is an independent event and is incidental to fruit abscission. There can be seed abortion without fruit drop, as sometimes occurs when carbaryl is used, and there can be fruit abscission without seed abortion. Stahly and Williams (40) applied bands of 2,3,5-triodobenzoic acid (TIBA) in lanolin to 'Delicious' fruit stems and caused fruit abscission without seed abortion. The TIBA lanolin band slightly injured the stems, which could have stimulated enough ethylene to promote abscission; however, the important observation was the seeds in the abscised fruits were still turgid and appeared healthy.

The number of seeded fruit on a tree will affect the amount of return bloom. Carbaryl causes more seed abortion than NAA and, in contrast to NAA, consistently increases return bloom (table 8). Chan and Cain (12) found that the number of seedless fruit on a tree does affect return bloom and suggested that the amount of seed formation is a controlling factor in flower initiation. Biennial bearing cultivars such as 'Golden Delicious' have a high complement of seeds in the fruit. Self-pollinated 'Golden Delicious' fruit contain fewer seeds than cross-pollinated fruit, and biennial bearing is not as pronounced in self-pollinated orchards. The consistent return bloom response with carbaryl is likely related to its effect on reducing seed number. Seeds produce gibberellins and possibly other hormones that interfere with flower formation (12). An interesting observation is that spur-type 'Golden Delicious' trees with a fruit crop have more spur and terminal growth than similar trees with no crop. It is possible the seeds in the fruit produce enough GA to promote shoot growth.

Table 8.—Average diameter of 'Delicious' apples in various box-size<sup>1</sup> groups at 5-day intervals beginning 35 days from full bloom

Days past full bloom	Average fruit diameter per projected box size <sup>2</sup>								
	163	150	138	125	113	100	88	80	72
	-----Centimeters-----								
35	2.29	2.36	2.41	2.49	2.54	2.62	2.67	2.74	2.79
40	2.69	2.77	2.84	2.90	2.95	3.02	3.10	3.18	3.28
45	3.02	3.10	3.15	3.20	3.28	3.40	3.45	3.56	3.63
50	3.30	3.38	3.43	3.53	3.63	3.73	3.81	3.91	3.99
55	3.56	3.63	3.68	3.78	3.91	4.04	4.14	4.24	4.32
60	3.84	3.91	3.96	4.06	4.19	4.29	4.42	4.55	4.65
65	4.11	4.16	4.24	4.32	4.44	4.57	4.70	4.83	4.95
70	4.34	4.44	4.50	4.60	4.72	4.88	5.00	5.16	5.31
75	4.57	4.67	4.78	4.88	4.95	5.13	5.28	5.44	5.59
80	4.78	4.88	4.95	5.05	5.18	5.33	5.54	5.74	5.89
85	4.95	5.05	5.16	5.28	5.41	5.56	5.76	5.94	6.15
90	5.13	5.26	5.33	5.49	5.64	5.79	5.99	6.17	6.38
95	5.28	5.41	5.51	5.64	5.82	5.99	6.17	6.40	6.58
100	5.41	5.56	5.66	5.82	5.99	6.17	6.38	6.60	6.81

<sup>1</sup>Box size equals number of apples per 19 kg.

<sup>2</sup>Data collected over 15-year period at Wenatchee, Wash.

Following the application of thinning sprays, it is desirable to determine the onset and duration of fruit drop. Many fruit set counts have been taken at intervals after spray treatments. Some typical examples are given in table 9. With all chemicals, set usually was reduced over a period of 5 to 15 days after spraying. In 1961, the postspray period was warm, and fruit drop was completed 5 to 10 days after carbaryl had been applied. In 1962, the postspray period was much cooler, and drop was slower to start; also, drop continued for at least 5 days longer than in 1961.

Table 9.—*Effect of chemical sprays on duration and rate at which 'Golden Delicious' apples abscise'*

Treatment	Year	Fruit set for the following number of days after spraying:				
		0	5	10	15	35
		Percent				
Check	1959	100	84	70	56	20
DNOC	1959	100	52	40	20	18
Check	1960	100	52	33	20	19
DNOC	1960	100	14	12	11	10
Check	1959	100	75	60	53	53
NAA	1959	100	95	50	27	27
Check	1960	100	80	69	64	61
NAA	1960	100	66	30	30	30
Check	1961	100	90	84	76	50
Carbaryl	1961	100	45	33	30	31
Check	1962	100	94	90	81	70
Carbaryl	1962	100	92	80	47	35

Source: Batjer and Billingsley (4).

<sup>1</sup>The temperature following the spray application greatly affects time when abscission occurs. In areas with cool temperature, fruit abscission will not occur for at least 10 to 15 days or longer after application of thinning spray.

As mentioned, NAA does not always delay abscission. Data in table 9 for the 1960 experiment show no delay in abscission; however, the degree of thinning was similar to that of the 1959 experiment, in which early fruit drop was markedly retarded.

### Effects of Thinning Sprays on Fruit Size and Yield

In practically all chemical thinning experiments, fruit size has increased. If the thinning sprays appreciably reduce set, size differences between treated and check trees become apparent early in the growing season. Final differences in size, of course, are greater if check trees are not hand thinned. The greatest increase in fruit size is obtained when blossom thinning sprays are used.

In all experiments reported by Batjer and Billingsley (4), unsprayed check trees were hand thinned after 35 to 50 days from full bloom. If the crop appeared excessive, the chemically thinned trees were supplemented with

hand thinning. Generally, fruit size was roughly proportional to the amount of thinning. When the degree of thinning for the different chemicals was constant (table 10), the final fruit sizes were similar.

Table 10.—*Effect of different thinning sprays on fruit set, yield, size, and return bloom of apples<sup>1</sup>*

Cultivar and treatment	Years sprayed	Trials conducted	Results compared with untreated check			
			Fruit set	Yield	Size	Return bloom
----- <i>Number</i> -----			----- <i>Percent</i> -----			
Delicious:						
DNOC	9	10	67	93	113	160
NAA	5	9	69	92	111	154
Carbaryl	4	9	70	89	109	180
Winesap:						
DNOC	13	15	64	97	115	140
NAAm	7	13	67	93	103	150
Carbaryl	4	12	67	90	117	160
Golden						
Delicious:						
DNOC	11	17	63	102	115	392
NAA	7	8	60	94	112	410
NAAm	7	12	63	90	106	400
Carbaryl	3	8	61	96	115	350

<sup>1</sup>Data for selected trials in which reduction in fruit set were approximately the same for the different chemicals on a given variety.

Source: Batjer and Billingsley (4).

Exceptions to this relation were apparent in the fruit sizes of apples from 'Delicious' and 'Winesap' trees treated with NAAM. Under certain conditions, young fruit that did not abscise were suppressed in growth by NAAM. These fruits continued to develop, but final size was generally reduced. This characteristic of NAAM limits its use on 'Delicious'.

Table 10 shows that fruit yields associated with different treatments were about the same as the hand-thinned check yields. The use of chemical thinning sprays increases yield of quality fruit over a 2-year period by altering the biennial bearing habit. Obviously, if thinning sprays reduce fruit set below the limits of a capacity crop, yield will be adversely affected.

### Influence of Chemical Thinning on Alternate Bearing

Trees usually bear on alternate years because fruit set is excessive during the "on year." When the quantity of fruit on the tree in relation to the amount of foliage is excessive, fruit-bud formation is reduced or entirely prevented. Thus, in the season following the "on year," the reduction in bloom results in a short crop; then, under the conditions in the "off year," too many fruit buds form. Once begun, such a fruiting pattern tends to become established. Most cultivars bear more heavily on alternate years, and the yearly difference in fruit set

is more pronounced in certain cultivars than in others. A typical cycle of biennial bearing is shown in figure 4. This condition can occur on branches within a tree and between trees.

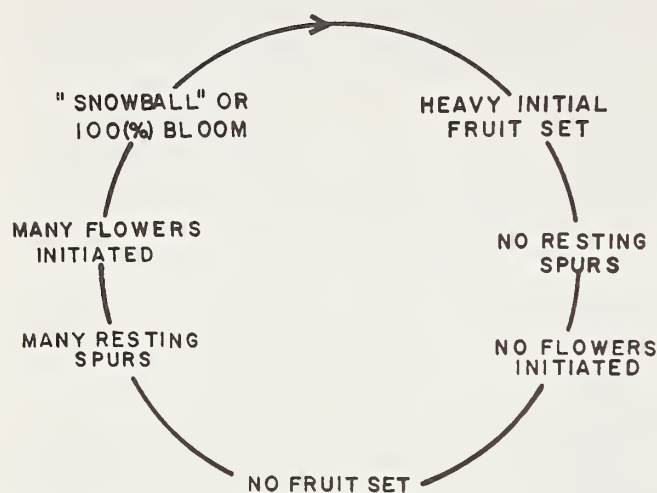


Figure 4.—Cycle of biennial bearing of apple trees. Individual limbs or whole trees may show this cyclic bearing pattern, depending on previous cropping and weather conditions.

Even cultivars considered regular in their bearing habits must be thinned very early to minimize the tendency toward alternation. Under most conditions, it is not feasible to hand thin biennial cultivars early enough to avoid pronounced alternation.

Perhaps the most outstanding feature of chemical thinning sprays is their effect on alternate bearing. These sprays reduce fruit set relatively early in the growing season, and the tree forms more fruit buds for the next year's crop. Table 9 illustrates this point. The amount of return bloom for a given cultivar was essentially the same for all types of thinning chemicals. As would be expected, the increase in return bloom was greatest on 'Golden Delicious', a cultivar with a pronounced tendency to alternate.

The favorable effects of thinning sprays on biennial bearing are well established. The behavior of the same trees treated with thinning sprays over several years is illustrated in table 11. If the amount of bloom exceeded 25 percent, all treated trees received a DNOC spray each year. During the entire experiment, fruit set, size, and yield records were obtained for individual trees. Also recorded were the number of hours of thinning labor required per tree. The sprayed treatments in the two orchards resulted in an average yearly increase in yield of 112 kg (table 11). This was because of the increased flowering and fruit set during the "off years." In one orchard (Bond), an average of 25 percent of the check trees each year bore less than 150 kg of apples. Only three sprayed trees during the entire 8 years of the experiment failed to produce that much fruit. Much less hand thinning was also an important result of the spray treatment.

Table 11.—Effect of DNOC sprays on the average yearly performance of 'Golden Delicious' apples in Washington State. The same trees were sprayed for 8 years if bloom exceeded 25 percent

Orchard	Fruit per 100 blossoming spurs		Yearly yield per tree		Hand-thinning time per tree	
	Sprayed	Check	Sprayed	Check	Sprayed	Check
—Number—						
Bond	49	85	540	435	0.3	1.7
Schell	57	95	975	855	1.9	4.7

Source: Batjer and Billingsley (4).

The date of thinning, whether by hand or with chemicals, greatly affects the amount of bloom the next year (fig. 5). Because of this relationship and the high amount of hand labor required for proper thinning, early chemical thinning is absolutely necessary for the annual production of apples.

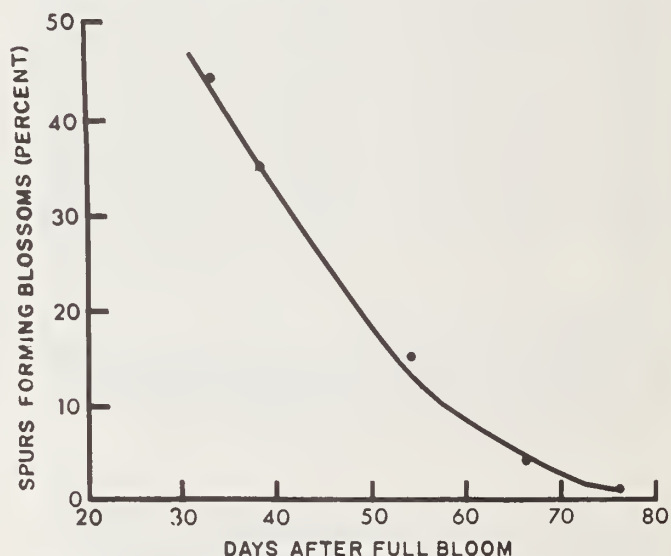


Figure 5.—Percentage of growing points forming blossoms on main leaders of a biennial-bearing 'Yellow Newtown' tree following periodic fruit thinning to one per 70 leaves 33, 38, 54, 66, and 76 days after full bloom in a bearing year at Wenatchee, Wash. (22).

The effect of chemical-thinning programs on annual production of apples in the United States is apparent in figure 6. Before 1949, considerable alternate-year production was evident. The year 1949 marked the beginning of the commercial application of chemical-thinning agents to apple orchards in the United States.

### Selection of a Thinning Program

Growers who have carefully studied and used chemical thinning for several years will be the most successful in their thinning programs. Since conditions differ each

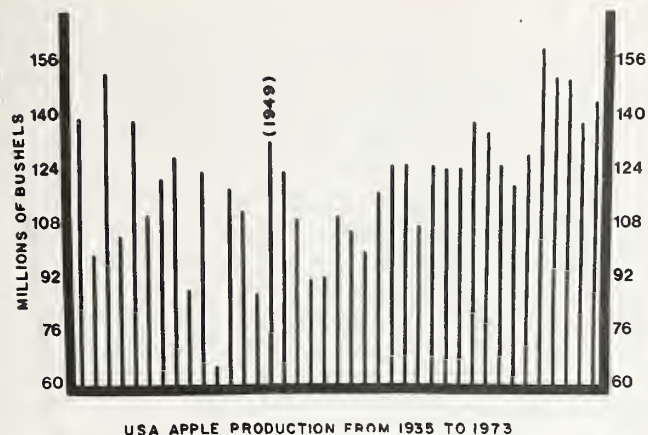


Figure 6.—Total U.S. apple production from 1935 to 1973. Note alternate-year bearing before 1949.

year, a grower needs three or more seasons' experience to develop a successful program for a particular orchard. Chemical thinning has been referred to as an art rather than a science. In some respects, this is true. Success requires practice and keen observation, along with a knowledge of the basic facts and variables involved. Because of the many variables, no single thinning procedure would be applicable to all orchards. Underthinning or overthinning may result from the same treatment in different orchards or in the same orchard in different seasons. Records of past orchard performance and management practices, including nitrogen fertilization, will be useful in determining whether the fruit will be easy or difficult to thin. Trees low in nitrogen tend to thin easily, but because of the low vigor do not initiate flowerbuds for the next year.

When trying to decide on a thinning program for a particular orchard, the grower should ask: "Will thinning be necessary?" and "Will the fruit be easy or difficult to thin?" The factors affecting the thinning response are listed in table 4. Various combinations of the conditions listed in table 4 can occur in an orchard each year. If easy-to-thin conditions are predominant, no chemical thinning may be needed. If easy- and difficult-to-thin conditions exist together, thinning sprays should be applied at moderate concentrations to fit the easy-to-thin conditions. If most of the difficult-to-thin situations are present, higher chemical concentrations are safe to use, and a program of two or three spray applications will be necessary.

A two- or three-spray program is often used on difficult-to-thin cultivars in the Western States. 'Golden Delicious' with a mature bearing habit can be sprayed at full bloom with DNOC at concentrations ranging from 160 to 480 g/100 L of water. If the weather is warm and little thinning occurs, the trees can be sprayed again at 7 to 10 days after bloom with 17 to 35 p/m of NAAm. At 20 to 22 days after full bloom, a final evaluation of thinning is made by actually pulling on the fruit in the clusters. If fruit are still firmly attached, a third spray of carbaryl is applied at a concentration of 120 to 180 g/100 L of water. In a self-pollinated orchard of

'Golden Delicious', the DNOC and NAAm sprays usually cause sufficient thinning. In cross-pollinated orchards, a growth regulator, such as ethephon or daminozide, is sometimes used with the thinning program to assure return bloom (see p.14). On mature bearing trees that are difficult to thin chemically, carbaryl can be applied earlier as part of the three-spray program at 10 to 14 days after bloom. There is no need to wait until results are obtained from the earlier sprays to proceed with the second or third spray. With the three-spray program, chemicals are used at moderate concentration, which reduces the risk of overthinning, as happens when only one or two sprays are used at high concentrations.

Most of the easy-to-thin cultivars, such as 'Delicious', are thinned after bloom with either NAA or carbaryl. In the Western States, carbaryl has been the most consistent postbloom thinner; however, some growers have been hesitant to use carbaryl since it may interfere with integrated mite control programs. This problem can be avoided if carbaryl is applied to the top and outer periphery of the tree, where most of the thinning is normally required. In this way, the spray will not interfere with the biological predators controlling the mite population in the interior of the tree.

The amount of fruit remaining after a DNOC blossom spray can be determined by observing the calyx or distal end of the fruit. If the green petallike structures, known as the calyx, are extended rather than folded down on the stem, the fruit will persist (fig. 7), and a postbloom thinning program will be required.

## Methods of Application

Because of variations in tree vigor and fruit-set patterns, a selective method of spray application is always desirable. Results are best when dilute sprays are applied with a high-pressure handgun. By this method, individual limbs or heavily loaded areas of the tree can be selectively treated without affecting the areas that require little or no thinning. It is a particularly valuable method for treating individual limbs or tops of spur-type trees with DNOC that bloom over a period of several days. Often, the lower part of the tree blooms first and can be sprayed with an airblast sprayer, and the followup spray for the late bloom can be applied by a handgun as needed. The extra labor required for the second spray is more than offset by the increase in return bloom.

Growers are often unable to cover their entire acreage during the thinning period with handgun sprayers. In such cases, an airblast sprayer can be used in the parts of the orchard where fruit set and tree vigor are fairly uniform. The lower spray jets should be turned off to prevent overthinning of fruit on the lower shaded branches. If cropping is to be consistent, sprayers equipped with handguns are very important in an orchard operation because they can be used to supplement airblast equipment.



PN-7014

Figure 7.—'Golden Delicious' fruitlet that will persist and continue to develop following a DNOC spray. Note extended calyx sepals compared with folded down sepals shown in figure 1.

Concentrate sprayers are used to apply insecticides, and many growers use them for growth regulators and chemical thinners. Under western conditions, concentrated solutions of thinning agents applied at rates of from 750 to 1000 L/ha have resulted in good thinning and return bloom on 'Delicious' but not on 'Golden Delicious', mainly because 'Golden Delicious' has such a strong tendency to alternate bearing. The amount of chemical per area of tree covered should be the same whether applied as a dilute or concentrate spray. The concentrate rates of the chemicals shown in table 2 are based on the dilute rate of 2800 L/ha.

The extent of fruit abscission depends on the amount of chemical absorbed by the foliage. Absorption is affected by the volume and concentration of the spray solution. Absorption is greatest while the leaves are wet with the spray. When the volume of water is reduced, the drying time is short, and the absorption potential is proportionately reduced. Thus, when the volume of water is small, the solution is higher in chemical concentration to compensate for the short drying time. Otherwise, chemical absorption and, hence, thinning effectiveness will be low. To satisfactorily use concentrate rather than dilute solutions of thinning chemicals, a grower should gain experience over a 3- to 5-year period by using the concentrate method of application and should compare the results with those for a dilute spray application.

The most consistent results are obtained with dilute applications. When the equipment is available for dilute

applications, the extra time involved with filling and mixing is more than offset by improved thinning response, fruit quality, and return bloom. DNOC is not usually applied as a concentrate spray because it is a caustic material that may cause excess foliage damage and serious overthinning, especially if cool, damp conditions prevail after application; however, some growers have used concentrate sprayers to apply DNOC with good results. A new thinning program, referred to previously, involves a concentrate application of DNOC plus Promalin on 'Delicious' apples, but grower usage has not been sufficient to determine the year-to-year variability and the dangers of overthinning.

Chemical thinners applied with aircraft are generally less effective. NAA and carbaryl can be applied by aircraft by adding extra surfactant or summer oil to the spray solution. If sprays cannot be applied with ground equipment, the use of aircraft, even though less effective, is better than no thinning.

### Increased Return Bloom by Combining Thinning Chemicals and Growth Regulators

Chemical-thinning agents have been successfully combined with growth regulators such as daminozide or ethephon to help overcome biennial bearing. The combinations are useful when the thinning agent is not a blossom spray, and they are also particularly effective on spur-type trees. At present, ethephon or daminozide is combined in the same tank with NAAm or carbaryl as a postbloom thinning spray, and NAA is often applied with carbaryl for more effective thinning (table 12). All treatments in table 12 can be used commercially on 'Golden Delicious'. The choice of treatment depends on the amount of bloom and the thinning needed. If bloom is less than 50 percent, DNOC may be omitted. The last two treatments, in which NAAm and ethephon are combined and applied at postbloom, look very promising

Table 12.—*Fruit set on 10-year-old "snowball" bloom 'Golden Delicious' trees after treatment with combination sprays of chemical thinning agents and growth regulators, Wenatchee, Wash.*

Treatment <sup>1</sup>	Fruit per 100 blossom clusters		Return bloom
	Number	Percent	
Control	95	2	
DNOC	67	4	
DNOC + NAAm + carbaryl	56	23	
NAAm + carbaryl	75	16	
DNOC + NAAm + daminozide	59	26	
NAAm + daminozide	71	28	
DNOC + NAAm + ethephon	43	72	
NAAm + ethephon	66	35	

<sup>1</sup>DNOC was applied at full bloom; the other chemicals were applied as a tank mix at 15 days after full bloom. Application rates, based on 2880 L/ha were: DNOC (375 p/m), NAAm (34 p/m), carbaryl (600 p/m), ethephon (450 p/m), and daminozide (1,000 p/m).

because a more even distribution of fruit occurs on the lower part of the tree and return bloom is excellent.

It is unnecessary to use the growth regulators daminozide and ethephon on all trees for flower promotion. Only young vigorous trees that are difficult to bring into bearing and biennial cultivars with a heavy bloom require growth regulators in addition to a good thinning program. With proper selection of rootstock and scion for early fruiting and judicious use of chemical thinning programs, supplemental growth regulator sprays are usually unnecessary. Growth regulators might be included in sprays used to thin a "snowball" bloom to help assure a bloom for the next year. The use of growth regulators on full-bearing trees in a light-bloom year may induce too much return bloom the following year and will encourage biennial bearing. When possible, avoid spraying light-bloom trees in a mature orchard. Growth regulators are also applied with thinning agents to improve fruit quality. An example of this is daminozide applied to 'Delicious' and 'Golden Delicious' to increase flesh firmness, reduce bruising, and delay development of water core.

When severe spring frosts occur, the trees will generally have a snowball bloom the next year regardless of the cultivar or rootstock. Therefore, steps must be taken to reduce initial fruit set and encourage flower initiation for the next year's crop. With some cultivars, such as spur 'Golden Delicious', an excessive bloom and heavy initial fruit set are enough to induce biennial bearing.

To maintain high annual production, a tree should be cropped heavily and kept vigorous enough so its return bloom is moderate (40 to 50 percent) rather than heavy (80 to 100 percent). A heavy bloom promotes biennial bearing and should, if possible, be avoided. When frost is not a serious hazard and the bloom is well distributed over the tree, a very small number of flowers are needed for a full crop of apples. When evenly distributed throughout the tree, fruit set on only 5 percent of the blossoms on a snowball-bloom tree is enough for a full crop.

### **Response of Spur-type Trees to Chemical Thinners**

Spur-type 'Delicious' and 'Golden Delicious' trees are more difficult than the standard type to keep bearing annually. Spur-type trees mature faster and show biennial bearing characteristics earlier than standard trees. Many spur-type trees are less vigorous than standard trees, and low vigor contributes to biennial bearing. Spur-type trees on dwarfing rootstocks tend to bear very heavily one year and poorly or not at all the next, especially in the early years of fruiting. To induce annual bearing, a chemical-thinning program is needed. Spur-type 'Delicious' and 'Golden Delicious' trees with more than 40 percent bloom should be sprayed with DNOC at bloom time and have an appropriate post-bloom thinning program.

Blossom thinning of spur-type trees is extremely important for a good return bloom. Often in spite of adequate thinning by late postbloom thinners, trees do not bloom the next year. This is especially true if the trees are low in vigor. To assure a return bloom on spur-type trees of all cultivars, the chemicals must be applied by 20 days after full bloom. When conditions permit, and the amount of bloom is greater than 40 percent, a DNOC full-bloom spray substantially benefits the trees. If bloom sprays cannot be used, apply an early combination postbloom spray of NAA and carbaryl, preferably at 7 to 15 days after bloom or within about 7 days from petal fall. Removal of excess fruit, with flower initiation in the interval between early fruit growth and flower initiation, helps guarantee flowers for the next year's crop. Thinning agents can be effective when applied as late as 30 days from bloom, but the amount of bloom the following year may be too sparse for a full commercial crop. Generally, the lower the tree vigor the shorter the period of flower initiation. Young, vigorous 'Delicious' trees can be influenced to initiate flowers as late as 5 to 6 weeks after bloom, whereas a mature 'Golden Delicious' tree in low to moderate vigor may not be influenced to flower after about 3 weeks from bloom. When growth regulators are used to promote flowering, the trees must have good vigor; otherwise, fruit size and vegetative growth can be excessively reduced.

### **Influence of Chemical Thinning Agents on Seed Abortion and Fruit Size**

Postbloom thinning agents, such as NAA and carbaryl, are known to cause seed abortion (8, 43, 57). The effects of these chemicals on seed number for several cultivars are shown in table 13. Carbaryl causes the most seed abortion in 'Delicious' fruit. Usually, warm weather following the application of the chemical causes stress in the tree, and most of the seedless fruit abscise. In some seasons, and especially in cool growing areas, 'Delicious' trees set fruit parthenocarpically. When postbloom thinners are used in cool seasons, the percentage of parthenocarpic fruit is increased. When weather conditions favor parthenocarpic fruit set (the number of seedless or low seed-count fruit persisting on the trees), overall fruit size will be noticeably reduced. Interestingly, the greater the percentage of parthenocarpic fruit on the tree, the higher the amount of return bloom (12). Carbaryl is therefore favored over other postbloom thinning agents because it promotes more consistent return bloom. NAA causes slightly less seed abortion, but return bloom is less than with carbaryl (table 14). The effect of seed number on fruit size of 'Delicious' was reported by Williams (56). Figure 8 indicates at least seven seeds per fruit are necessary for maximum fruit size. If maximum fruit size is to be obtained in the late-blooming cooler districts, it is advisable to rely more on the blossom thinners such as DNOC and ethephon and less on the postbloom chemicals. This is true even with the greater risk of overthinning at the earlier application date. Another alternative is to use the postbloom

Table 13.—*Effects on thinning sprays applied 17 days after full bloom on the seed content of several cultivars of apples, Wenatchee, Wash., 1960*

Cultivar	Experi- ments	Seedless fruit					Seed per fruit				
		Check	Carbaryl	NAA or		L.S.D. 0.05 level	Check	Carbaryl	NAA' or		L.S.D. 0.05 level
				NAAm	DNOC				NAAm	DNOC	
	<i>Num- ber</i>	-----Percent-----					-----Number-----				
Delicious Golden	4	13	47	19	12	12	5.1	2.9	4.2	4.9	1.9
Delicious	3	1	3	4	0	4	7.3	7.3	6.8	6.8	.5
Winesap	2	0	0	2	0	-	8.2	8.3	7.8	7.2	.6
Jonathan	2	1	5	0	-	10	5.8	5.5	5.7	-	1.5

'Delicious and Jonathan apples were sprayed with NAA; Winesap and Golden Delicious apples were sprayed with NAAm.

Source: Batjer and Billingsley (4).

Note: Dashes indicate no data.

Table 14.—*Effects of carbaryl and NAA on seed content of 'Spur Delicious' apples, Wenatchee, Wash.:*

Orchard and treatment	Seed per fruit	Seedless fruit
	Number	Percent
Orchard A (not thinned):		
Check	14.4	17
NAA (5 p/m)	3.7	38
Carbaryl (1,130 g/ha)	3.2	43
Orchard B (size thinned):		
Check	6.1	4
NAA (5 p/m)	5.0	8
Carbaryl (1,130 g/ha)	4.8	12

'Average of 400 fruit.

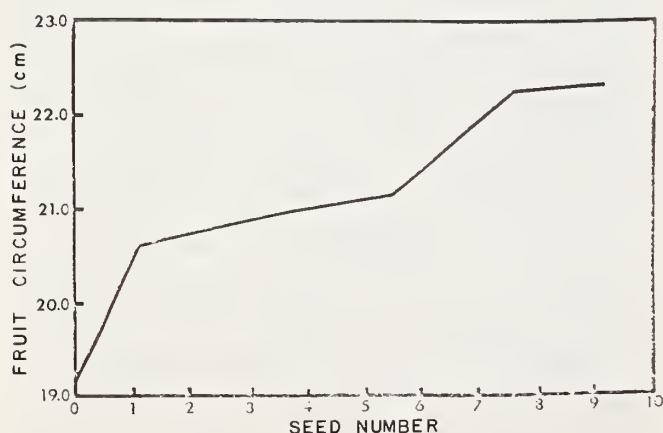


Figure 8.—Relation between number of seeds per fruit and size of 'Red Delicious' fruit at harvest, 1976.

chemicals at as late an effective date as possible to take advantage of the warmer days, which will increase stress and subsequent thinning.

### Need for Hand Thinning After Chemical Thinning

Because 'Delicious' tends to set fruit parthenocarpically in some areas and seasons and postbloom thinners cause seed to abort, it is important to remove the small, unmarketable, low seed-count fruit during a followup hand-thinning operation.

When good thinning is obtained with chemicals, it is possible to delay hand thinning until 50 or 60 days from bloom because by then the small fruit can be readily distinguished from the large fruit. The important thing to remember is that a small fruit will always be small, regardless of the removal of competition. The effect of initial fruit size on final fruit size is shown in figure 9. A volume difference of 11.7 cm<sup>3</sup> (1.7-cm circumference) at 50 days after bloom results in a difference of six box sizes (from 138 to 72) at harvest. For this reason, it is important to hand thin by fruit size as well as by distance between fruit.

The amount of fruit left on a tree should be determined by the vigor and general condition of the tree. Leaf area per fruit affects the number of spurs flowering the following year. Data of Harley et al. (23), who examined the effects of different leaf areas and periods of thinning after full bloom on blossom-bud formation in different cultivars, are presented in table 15. The leaf-fruit adjustments were made on main leaders of a single biennial-bearing tree of each cultivar. Tree vigor, as designated in their study, was evaluated on the basis of leaf size and color at the time of thinning. Trees with dark-green leaves that were large for the cultivar were classified as high in vigor. Trees with small, light-green leaves were considered as low in vigor. Lengths of terminal growth have been employed as a measure of vigor, but the measure is subject to much criticism in studies relating to blossom-bud formation. Conceivably, vigor may be rated high on the basis of shoot length and leaf color yet leaf injury from diseases, insects, or

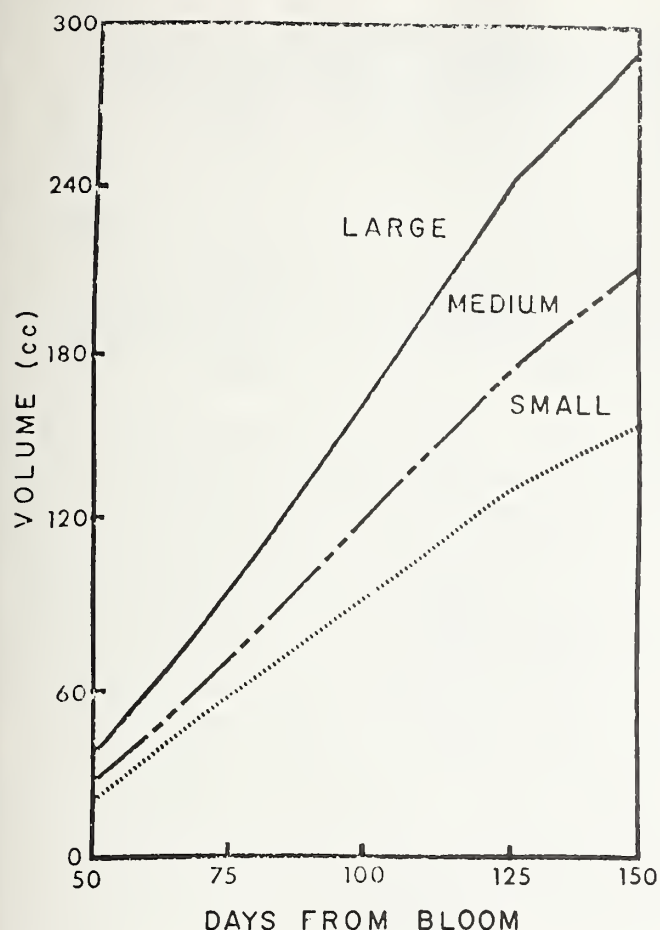


Figure 9.—Growth curves for small (138), medium (100), and large (72) 'Red Delicious' fruit 1976.

chemical spray may be severe enough to reduce blossom-bud development. Because of the lack of correlation with shoot growth, tree vigor should be estimated in terms of leaf size, depth of green color, and general leaf condition. Leaf nitrogen (N) content is correlated with leaf color and can be used as a guide for proper fertilization. For maximum production of high-quality 'Golden Delicious', a leaf N content of 1.9 to 2.1 percent is optimum (58).

Final hand thinning should be based on potential fruit size at harvesttime, which can be predicted quite accurately at 50 to 70 days after full bloom. A fruit-size prediction chart (5, 48) can be used successfully for harvest-size predictions (table 8, p. 10). After fruit are measured and potential harvest size is determined, it is easier to decide which fruit are too small and should be removed by hand.

After chemical thinning, the fruit may be unevenly spaced along a limb in clusters, and they often can be left in clusters of at least two and possibly three. 'Delicious' strains with poor coloring have to be thinned to singles, but strains with good coloring and other cultivars, such as 'Golden Delicious' and 'Granny Smith',

Table 15.—Effect of fruit thinning on individual main leaders of biennial-bearing 'Yellow Newtown', 'Winesap', and 'Delicious' trees in 1935 on blossoming in 1936 at Wenatchee, Wash.

Vigor and cultivar	Period from full bloom to thinning	Leaves per fruit after thinning	Average leaf area per fruit	Growing points blossoming
	Days	Number	Square centimeters	Percent
High vigor:				
Yellow Newtown	17	30	664	50.6
	17	50	1110	68.0
	32	30	665	27.2
	32	50	1110	20.0
	32	70	1484	49.4
	60	125	497	.5
Winesap	32	30	297	18.0
	32	50	497	44.0
	32	70	697	77.5
	68	125	252	2.5
	68	125	252	4.0
Delicious	23	25	374	35.6
	31	30	445	28.2
	31	40	594	37.5
	39	25	374	12.3
	39	30	445	31.3
	--	(?)	77	1.5
Low vigor:				
Delicious	32	30	323	5.0
	32	50	535	3.0
	32	70	748	15.7
	68	120	213	0

<sup>1</sup>Leaders originally selected as unthinned checks but were later commercially thinned by grower-owner. Leaves per fruit arrived at by counting a representative number of leaves and fruits after thinning was performed.

<sup>2</sup>Unthinned.

Source: Harley et al. (22).

Note: Dashes indicate no data.

can be left in clusters. When thinned to singles, 'Golden Delicious' produce fruit that are too large. A 'Golden Delicious' tree in good vigor will consistently produce more fruit of optimum marketable size if most of the fruit are carried on part of the spurs in two's and three's. If every spur bears a fruit, no resting spurs will remain to initiate fruit buds for the next year's crop and biennial bearing will result. The effect of size thinning on the number of seedless fruit persisting at harvest is shown in table 14. Final fruit size was much better in orchard B than in orchard A because orchard B was hand thinned after chemical thinning. Hand thinning by size of fruit removed a high percentage of the small, seedless, and low-seed-count fruit. When the crop is light, the small fruit can be left on the tree and used for processing.

Excessive hand thinning following chemical thinning is a very costly mistake made by some fruit growers. The old thinning method was to arbitrarily space the fruit on a limb and thin every cluster to a single fruit. Today, with the insecticides available for controlling codling moth, the conventional spacing method is outmoded and undesirable.

### Chemical Thinning of Pears

The same environmental and physiological factors affecting the response of apple fruit to chemical thinning agents will also affect pears. For information on these factors, see "Factors Affecting Fruit Abscission." Pears are generally more sensitive to NAA and NAAM than apples. Low concentrations of NAA can seriously overthin young 'Anjou' trees and are phytotoxic on the 'Seckel' cultivar.

The need for thinning pears varies by region and cultivar. 'Bartlett' (Williams) pears are seldom thinned in California, but in Washington and Oregon they require extensive thinning to attain acceptable market size. Considerable research has been done to perfect chemical and hand-thinning techniques for 'Bartlett' pears, and a harvest-size prediction chart has been prepared as a guide for size thinning the fruit (53, 54, 55, 60, 61). Similar hand thinning techniques could be used for other cultivars. Sensitivity to chemicals varies considerably among cultivars. Use caution with 'Anjou' and 'Seckel' since they are very sensitive to NAA. Gibberellic acid applied during the off year is quite effective in preventing excessive flowering of 'Seckel' pears (30). This principle may be of use on other cultivars.

If the set of fruit on the tree as a whole is excessive, reduce the clusters to one or two fruit by removing the smaller pears. On the other hand, if the set of fruit on the tree is not excessive, fruit in these clusters will reach satisfactory size and quality with minimal thinning.

It is impossible to lay down hard-and-fast rules for the thinning of pears. The number of fruit a tree will develop to good marketable size will vary with its vigor and the growing conditions. With nearly all cultivars, from 30 to 40 good leaves per fruit are essential for the manufacture of materials that produce fruit; however, these leaves need not be directly adjacent to the fruit. With extremely heavy sets of fruit, thinning to reduce the amount of fruit in proportion to the leaf system is essential if fruit of best size and quality is to be obtained. Since fruit that is small at thinning time tends to remain small, it should be removed. As the natural drop is usually over about 6 weeks after bloom, the earlier the thinning is done the greater is the effect on improving the size of the remaining fruit.

In some areas, particularly California, growers rely solely on selective picking to supply the necessary thinning. When pears of 6.17 cm in diameter and larger are removed in the first picking, the fruit remaining on the tree will likely increase in volume at a daily rate of about 2 percent. Thus, about 1 week is required to obtain an increase of 0.3 cm in diameter for the remaining

fruit; however, since both shipping and canning quality can be seriously impaired, 'Bartlett' pears should not be permitted to remain too long on the trees for size increase. This practice is seldom used in Oregon or Washington; thus, early thinning with chemicals or by hand is very important.

High labor costs have encouraged the use of chemicals for thinning 'Bartlett' pears. The ideal practice is to remove most of the excess fruit with chemical sprays and use supplemental hand thinning to adjust the fruit load. Quality of the remaining fruit is improved by hand removal of the small, marked, and misshapen fruit.

Fruit set and size of 'Bartlett' pears have been determined after spraying with different rates of NAA and naphthaleneacetamide (NAD). Both NAA and NAD reduce fruit set (table 16). NAD is used at a rate of 10 to 15 p/m. NAA is used at a rate of 15 to 20 p/m. An appropriate surfactant, such as Regulaid or Tween 20, is used with both chemicals at the rates indicated. The effective concentration may vary from one district to another; thus, local authorities should be consulted for correct application rates. NAAM causes flattening of the leaves, and high rates of this chemical can result in overthinning. The leaf-flattening symptom does not affect the tree or growth of the fruit. The most effective time of application is at 15 to 20 days after full bloom. NAA usually will not cause overthinning. Chemical thinning can increase the size of the remaining fruit by up to 18 percent; however, the increase in size of the fruit is generally small considering the earliness of thinning and the amount of thinning obtained (table 16).

The grower should know at hand-thinning time which fruit will be large enough at harvest to satisfy the market requirements. After chemical thinning and in light crop years, the tendency is to overthin the remaining fruit and seriously reduce profits. Many growers space thin pears, using the same spacing of 20 to 25 cm as used for apples, with the assumption that a similar increase in size of remaining fruit is obtained with pears as with apples. Research on fruit growth after chemical and hand thinning indicates that pears do not benefit from thinning to the same extent as apples. Avoid the practice of heavy thinning by spacing of fruit to increase fruit size.

A method of predicting harvest size at thinning time is presented here as a guide for size-thinning 'Bartlett' pears. Table 1 is used for predicting the final size of fruit at harvesttime. The data are from 10 years of actual fruit measurements at Wenatchee, Wash., and are useful in determining which fruit will be too small to meet grade standards at harvest. If a 5.72-cm-diameter pear is desired at a harvesttime of 125 days from bloom, the fruit should be a minimum of 2.69 cm in diameter at 60 days from bloom (table 17). If harvest date is advanced to 110 days from bloom, the fruit should be 3.20 cm in diameter at 60 days from bloom to meet the desired minimum harvest size of 5.77 cm. All fruit smaller than these measurements should be removed at thinning time. A small pear grows at about

Table 16.—*Fruit set and increase in size of remaining fruit after chemical thinning of Bartlett pears in orchards in 3 different years<sup>1</sup>*

Year and chemical concentration	Orchard							
	1		2		3		4	
	Fruit set <sup>2</sup>	Size increment <sup>3</sup>	Fruit set <sup>2</sup>	Size increment <sup>3</sup>	Fruit set <sup>2</sup>	Size increment <sup>3</sup>	Fruit set <sup>2</sup>	Size increment <sup>3</sup>
	Num-ber	Per-cent	Num-ber	Per-cent	Num-ber	Per-cent	Num-ber	Per-cent
1st year:								
Check	60	0	55	0	42	0	--	--
NAA 5 p/m	53	8	43	6	43	0	--	--
NAA 10 p/m	44	6	39	11	44	6	--	--
NAD 10 p/m	55	6	34	9	40	4	--	--
NAD 20 p/m	39	9	33	6	38	4	--	--
2d year:								
Check	45	0	51	0	60	0	60	0
NAA 10 p/m	35	5	35	7	40	11	40	4
NAD 15 p/m	25	12	25	15	22	11	25	15
3d year:								
Check	62	0	--	--	--	--	--	--
NAA 15 p/m	32	18	--	--	--	--	--	--
NAD 10 p/m	34	9	--	--	--	--	--	--

<sup>1</sup>Sprayed 14 days after bloom.

<sup>2</sup>Number of fruit per 100 blossoming clusters.

<sup>3</sup>Based on 100 fruit measured at random from each of 5 trees per treatment.

Note: Dashes indicate no data.

Table 17.—*Harvest-size prediction table for Bartlett pears*

Fruit size at designated days from full bloom							
Size-prediction period				Harvest period			
60	65	70	75	100	100	120	125
<i>Diameters in centimeters</i>							
2.69	2.97	3.25	3.48	4.75	5.18	5.58	5.72
2.97	3.25	3.78	5.03	5.46	5.46	5.84	5.99
3.20	3.48	4.01	5.33	5.77	5.77	6.17	6.32
3.40	3.71	4.27	5.64	6.10	6.10	6.48	6.65
3.63	3.94	4.52	5.92	6.40	6.40	6.81	6.96
3.84	4.14	4.45	6.20	6.68	6.68	7.11	7.29
4.14	4.45	4.75	6.50	7.01	7.01	7.44	6.62
4.45	4.75	5.05	6.81	7.32	7.32	7.72	7.92

correlation, the data in table 1 can be used as an excellent guide for size-thinning 'Bartlett' pears. Some variation in results will occur in different pear districts because of climatic differences and specific cultural practices such as frequency of irrigation and fertilization; however, adjustments can be made by the individual grower at thinning time to allow for the effect of climate, high or low tree vigor, and cultural practices on fruit growth. For example, it may be necessary to leave only the fruit that are large enough at 60 days from bloom to obtain pears 6.17 cm in diameter at harvest, rather than the smaller ones predicted to be 5.72 cm in diameter. This would allow a margin of safety for adverse growing conditions.

Hand thinning of 'Bartlett' pears after 70 days from bloom does not result in an appreciable increase in size of the remaining fruit. Most of the benefit from thinning at that time is in removal of cull fruit and, in some cases, larger sound fruit to prevent limb breakage. Contrary to popular belief, 'Bartlett' pears on healthy trees can be left in clusters of two or three, and still attain desirable quality and size, provided the limb will support the fruit load. This can be done because improved spray practices control insect pests and the benefit obtained from space thinning 'Bartlett' pears is small, especially when thinned after 70 days from bloom.

the same rate as a large one, but because it is small to begin with it will be smaller at harvesttime regardless of the amount of thinning done.

The correlation between early fruit size and final harvest size is very high (15). At 60 days after bloom, the final size can be predicted to within 0.3 cm in diameter 90 percent of the time. Because of this close

Many growers are using size thinning to improve quality and yield of pear fruit. On a given day, a thinning crew can be given a sample fruit, or a wire-sizing gage, and instructed to remove all fruit smaller than the sample fruit and if necessary do some space thinning to reduce limb breakage. This system prevents overthinning of trees capable of carrying and sizing heavy crop loads.

## Literature Cited

1. Auchter, E.C., and J.W. Roberts. 1934. Experiments in the spraying of apples for the prevention of fruit set. *Proceedings of the American Society of Horticultural Science* 30:22-25.
2. Bagenal, N.B., W. Goodwin, E.S. Salmon, and W.M. Ware. 1925. Spraying experiments against apple scab. *Journal of the Ministry of Agriculture (Great Britain)* 32:137-150.
3. Batjer, L.P. 1964. Fruit thinning with chemicals. U.S. Department of Agriculture Agriculture Information Bulletin No. 289, 27 p.
4. ——— and H.D. Billingsley. 1964. Apple thinning with chemical sprays. Washington State Agricultural Experiment Station Bulletin No. 651, 24 p.
5. ——— H.D. Billingsley, M.N. Westwood, and B.L. Rogers. 1957. Predicting harvest size of apples at different times during the growing season. *Proceedings of the American Society of Horticultural Science* 70:46-57.
6. ——— and M.B. Hoffman. 1951. Fruit thinning with chemical sprays. U.S. Department of Agriculture Circular No. 867, 46 p.
7. ——— and A.H. Thompson. 1948. Three years' results with chemical thinning of apples in the Northwest. *Proceedings of the American Society of Horticultural Science* 52:164-172.
8. ——— and B.J. Thomson. 1961. Effect of 1-naphthyl N-methylcarbamate (Sevin) on thinning apples. *Proceedings of the American Society of Horticultural Science* 77:1-8.
9. ——— and M.N. Westwood. 1960. 1-naphthyl N-methylcarbamate, a new chemical for thinning apples. *Proceedings of the American Society of Horticultural Science* 75:1-4.
10. Burkholder, C.L., and M. McCown. 1941. Effect of scoring and of a naphthyl acetic acid and amide spray upon fruit set and of the spray upon preharvest fruit drop. *Proceedings of the American Society of Horticultural Science* 38:117-120.
11. Byers, R.E. 1978. Chemical thinning of spur Golden Delicious and Bisbee Delicious with Sevin and Vydate. *HortScience* 13:59-61.
12. Chan, B.G., and J.C. Cain. 1967. The effect of seed formation on subsequent flowering in apple. *Proceedings of the American Society of Horticultural Science* 91:63-68.
13. Davidson, J.H., O.H. Hammer, C.A. Reimer, and W.C. Dutton. 1945. Thinning apples with the sodium salt of naphthyl acetic acid. *Michigan Agricultural Experiment Station Quarterly Bulletin No. 27*:352-356.
14. Donohoe, C.W., Jr. 1968. The relationship of date of application and size of fruit to the effectiveness of NAA for thinning apples. *Proceedings of the American Society of Horticultural Science* 92:50-62.
15. Edgerton, L.J. 1973. Chemical thinning of flowers and fruits. *In* Shedding of plant parts, T.T. Kozlowski, editor, p. 435-474, Academic Press Inc., N.Y.
16. ——— and W.J. Greenhalgh. 1969. Regulation of growth, flowering and fruit abscission with 2-chloroethanephosphonic acid. *Journal of the American Society of Horticultural Science* 94:11-13.
17. Forshey, C.G., and M.B. Hoffman. 1966. Factors affecting chemical thinning of apples. N.Y. State Agricultural Experiment Station Research Circular, Series 4. Ithaca.
18. Freed, V.H. 1957. Absorption of aminotriazole as influenced by surface tension. Oregon State College (Agricultural Chemicals Department), Corvallis.
19. ——— and M. Montgomery. 1958. The effect of surfactants on foliar absorption of 3-amino-1,2,4-triazole. *Weeds* 6:386-389.
20. Gardner, F.E., C. Marth, and L.P. Batjer. 1939. Spraying with plant growth substances for control of the preharvest drop of apples. *Proceedings of the American Society of Horticultural Science* 37:415-428.
21. Grauslund, Jorgen. 1978. Fruit thinning. IV. A review on chemical fruit thinning. *Saertryk af Tidsskrift for Planteavl* 82:521-539.
22. Harley, C.P., J.R. Magness, M.P. Mosure, and others. 1942. Investigations on the biennial bearing of apple trees. U.S. Department of Agriculture Technical Bulletin No. 792, 58 p.
23. ——— H.H. Moon, and L.O. Regeimbal. 1957. Effects of the additive Tween 20 and relatively low temperatures on apple thinning by naphthaleneacetic acid sprays. *Proceedings of the American Society of Horticultural Science* 69:21-27.
24. Hildebrand, E.M. 1944. The mode of action of the pollenicide, elgetol. *Proceedings of the American Society of Horticultural Science* 45:53-58.
25. Hoffman, M.B. 1953. Safer thinning sprays for apples. *Proceedings of the New York State Horticultural Society* 98:128-135.

26. ———. 1969. Spray thinning. *American Fruit Grower*, Western Edition. March, p. 18-19.
27. Lee, Beatrice, and J.H. Priestley. 1924. The plant cuticle. I. Its structure, distribution and function. *Annual Botany* 38:525-545.
28. Lombard, Porter, and John Strang. 1978. Thinning Seckel pears for best return. *Proceedings of the Oregon State Horticultural Association* 69:56-57.
29. Luckwill, L.C. 1953. Studies of fruit development in relation to plant hormones. II. The effect of naphthalene acetic acid on fruit set and fruit development in apples. *Journal of Horticultural Science* 28:25-40.
30. ——— and C.P. Lloyd-Jones. 1962. The absorption, translocation and metabolism of 1-naphthaleneacetic acid applied to apple leaves. *Journal of Horticultural Science* 37:190-206.
31. MacDaniels, L.H., and E.M. Hildebrand. 1940. A study of pollen germination upon the stigmas of apple flowers treated with fungicides. *Proceedings of the American Society of Horticultural Science* 37:137-140.
32. Magness, J.R., L.P. Batjer, and C.P. Harley. 1940. Spraying apples for blossom removal. *Proceedings of the American Society of Horticultural Science* 37:141-146.
33. Marsh, H.V., Jr., F.W. Southwick, and W.D. Weeks. 1960. The influence of chemical thinners on fruit set and size, seed development, and preharvest drop of apples. *Proceedings of the American Society of Horticultural Science*. 75:5-21.
34. Rogers, B.L., and A.H. Thompson. 1969. Chemical thinning of apple trees using concentrate sprays. *Journal of the American Society of Horticultural Science* 94:23-25.
35. ——— and G.R. Williams. 1977. Chemical thinning of spur-type Delicious apple trees. *Virginia Fruit* 65:23-28.
36. Russel, H.A., and S. Pickering. 1919. *Science and fruit growing*. Macmillan, N.Y.
37. Schneider, G.W., and J.V. Enzie. 1943. The effect of certain chemicals on the fruit set of apples. *Proceedings of the American Society of Horticultural Science* 42:167-176.
38. Southwick, F.W., and W.D. Weeks. 1949. *Proceedings of the American Society of Horticultural Science* 53:143-147.
39. ——— W.D. Weeks, E. Swada, and J.F. Anderson. 1962. The influence of chemical thinners and seeds on the growth rate of apples. *Proceedings of the American Society of Horticultural Science* 80:33-42.
40. Stahly, E.A., and M.W. Williams. 1972. Effect of plant growth regulators on apple fruit and pedicel abscission. *Journal of the American Society of Horticultural Science* 97(6):724-726.
41. Stebbins, R.L. 1962. Effect of 1-naphthyl N-methylcarbamate (Sevin) as a chemical thinner for apples in western Colorado. *Proceedings of the American Society of Horticultural Science* 80:11-14.
42. Struckmeyer, B. Ester, and R.H. Roberts. 1950. A possible explanation of how naphthaleneacetic acid thins apples. *Proceedings of the American Society of Horticultural Science* 56:76-78.
43. Teubner, F.G., and A.E. Murneek. 1955. Embryo abortion as mechanism of "hormone" thinning of fruit. *Missouri Agricultural Experiment Station Research Bulletin* No. 590, 27 p.
44. Thompson, Arthur H. 1957. 6 years' experiments on chemical thinning of apples. *Maryland Agricultural Experiment Station Bulletin* No. A-88, 46 p.
45. Tukey, L.D. 1965. Fruit-size timing in chemical thinning of apple trees. *Transactions of the Illinois Horticultural Society* 99:67-79.
46. Veinbrants, N. 1979. Further studies on the use of 2-chloroethyl-phosphonic acid (ethephone) as a thinning agent for apples. *Australian Journal of Experimental Agriculture and Animal Husbandry* 19:611-615.
47. Walsh, C.S., H.J. Swartz, and L.J. Edgerton. 1979. Ethylene evolution in apple following postbloom thinning sprays. *HortScience* 14(6):704-706.
48. Washington State University Extension Service. 1964. Fruit size prediction chart, No. C-85 5M 568. Washington State University Extension Service, Pullman.
49. ———. 1980. Spray guide for eastern Washington. *Washington State University Extension Bulletin* No. 419, 56 p.
50. Westwood, M.N., and L.P. Batjer. 1958. Factors influencing absorption of dinitro-ortho-cresol and naphthaleneacetic acid by apple leaves. *Proceedings of the American Society of Horticultural Science* 72:35-44.
51. ——— and L.P. Batjer. 1960. Effects of environment and chemical additives on absorption of naphthaleneacetic acid by apple leaves. *Proceedings of the American Society of Horticultural Science* 76:16-29.
52. ——— L.P. Batjer, and H.D. Billingsley. 1960. Effects of environment and chemical additives on absorption of dinitro-o-cresol by apple leaves. *Proceedings of the American Society of Horticultural Science* 76:30-40.
53. Williams, M.W. 1972. Chemical thinning and prediction of harvest size of Bartlett pears. *Proceedings of the Symposium on Pear Growing, Fruit Breeding Station, Anjers, France*, p.51-60.
54. ———. 1973. Chemical thinning and guide for size thinning Bartlett pears. *Proceedings of the Washington State Horticulture Association*, p. 55-59.
55. ———. 1977. Fruit set of Anjou and growth of Bartlett (Williams) pears. *Acta Horticulturae, Pear Growing*, p.69.

56. ————1977. Adverse weather and postbloom thinning chemicals can affect seed content and size of Red Delicious apples. Proceedings of the Washington State Horticulture Association, p. 157-161.
57. ————1979. Retention of fruit firmness and increase in vegetative growth and fruit set of apples with aminoethoxyvinylglycine. HortScience 15(1):76-77.
58. ————and L.P. Batjer. 1964. Site and mode of action of 1-naphthyl N-methylcarbamate (Sevin) in thinning apples. Proceedings of the American Society of Horticultural Science 85:1-10.
59. ————and H.D. Billingsley. 1974. Effect of nitrogen fertilizer on yield, size and color of 'Golden Delicious' apple. Journal of the American Society of Horticultural Science 99:144-145.
60. ————and H.D. Billingsley. 1978. Suggested commercial use of Promalin to improve Delicious apple shape and size. Proceedings of the Washington State Horticulture Association p. 36-40.
61. ————H.D. Billingsley, and L.P. Batjer. 1969. Early season harvest size prediction of 'Bartlett' pears. Journal of the American Society of Horticultural Science 94(6):596-598.
62. ————H. Melvin Couey, Harold Moffitt, and Duane L. Coyier. 1978. Pear production. U.S. Department of Agriculture, Agriculture Handbook No. 526, 53 p.



U.S. DEPARTMENT OF AGRICULTURE  
SCIENCE AND EDUCATION ADMINISTRATION  
WASHINGTON, D.C. 20250

OFFICIAL BUSINESS  
PENALTY FOR PRIVATE USE, \$300

POSTAGE AND FEES PAID  
U. S. DEPARTMENT OF  
AGRICULTURE  
AGR 101

